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Digestion versus composting of straw and hay: effects on composition of biomass residues

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Abstract

An experiment was done to compare the effect of two decomposition processes, digestion and composting, on the quality of the final residue from two substrates: hay and straw. The digestion was done by using dwarf goats on digestion crates and the composting process was simulated in buckets. The composting was allowed to continue to the same level of organic matter loss as achieved in the digestibility trial. The results indicate that the pattern of biomass decomposition as measured by the fibre analysis in Goering and Van Soest method was similar between both processes and substrates. Absolute amounts of acid detergent lignin (ADL) did not change significantly throughout both decomposition processes, but the quantity of other fibre components decreased. Chemically, the ADL fraction makes up a large part of the humus in the soil and though the results are variable, they suggest that the initial ADL content of a substrate indicates its humus building capacity. Concerning the nitrogen fractions, however, there were larger differences between the decomposition processes and substrates. Digestion left less nitrogen in the organic matter than composting, and the composting of straw even resulted in a net increase in nitrogen content.

Keywords: composting, digestion, humus, lignin, nitrogen.

Introduction

In agriculture, a major part of the organic matter production that is not used for human consumption is returned to the soil. This can take place either directly in the form of roots, mulch and stubble, or indirectly after a composting process, or digestion by livestock. During the decomposition of this – generally fibrous – organic matter, plant nutrients are released or incorporated into microbial biomass. The residue consists of humus and humus like substances, hereafter simply called 'humus', a chemically not well defined substance (MacCarthy *et al.*, 1990a). 'Humus' in that sense is closely related to what is called the Acid Detergent Lignin (ADL), a fibre component that is also commonly measured in the analysis of nutritive value of biomass for animal feed (Stevenson, 1965; Goering & Van Soest, 1970). The nutrients released in the soil during the decomposition of organic matter have a direct effect on crop production. The 'humus' has an indirect effect due to its influence on several soil properties such as cation exchange capacity, stability of soil structure and water holding capacity (Stewart *et al.*, 1987; MacCarthy *et al.*, 1990b).

Crop byproducts like straw, and other crop biomass such as from grass or green manure can be used for feeding of either livestock or soil organisms, a choice to be made particularly in farming systems with an organic matter shortage (Lal, 1988; Budelman & Van der Pol, 1992; De Ridder & Van Keulen, 1990). In that case it is important to compare the effect of digestion by livestock and composting by microorganisms on the levels of organic matter in soils. Animal production may influence the fate of organic matter in more than one way, for example by trampling, extra tillage or foraging. This will respectively result in extra soil compaction, increased soil organic matter decay or lack of mulch, i.e. higher soil temperature or different moisture gradients. Also, digestion and composting prior to application to the soil results in a reduced amount of fresh organic matter available for the soil organisms. Decomposition by soil fauna may affect the amount and quality of the remaining soil organic matter. For example, digestion by earthworms results in a higher organic matter content, probably because of physical protection of the organic matter that remains in the worm casts (Marinissen, 1995). However, that effect does not much concern the difference between decomposition through either digestion by ruminants or composting. The experiment reported in this paper focuses on only two questions:

- does the decomposition of organic material by livestock (digestion) and aerobic microbial action (composting) result in a different composition of the residues in terms of fibre and nitrogen fractions?
- is there an effect of the original substrates on the composition of the residue obtained from either digestion or composting?

From the many ways to characterize complex materials as fodder, manure and compost we used the analysis for fibre fractionation as developed by Goering & Van Soest (1970) for the evaluation of nutritive value in animal feed.

Material and methods

Treatments

The digestion and composting of two different substrates, grass hay (well digestible, high protein feed) and wheat straw (less digestible, low protein feed), were compared. Their composition in terms of fibre and nitrogen is shown in Tables 1 and 2.

The digestibility of the feeds was measured by feeding them to West African Dwarf Goats on digestion crates as a model for ruminant digestion (Schneider & Flatt, 1975). After two weeks, the goats were adapted to the feed, after which their

Table 1. The amount of dry matter (DM), neutral detergent solubles (NDS), neutral detergent fibre (NDF) and acid detergent lignin (ADL) in hay, straw and their corresponding dung and composts (mg g^{-1} original feed dry matter)

	DM	NDS	NDF	ADL
Hay feed	1000 a	340	660 a	37 a
Hay manure	385 b	164	221 b	47 a
Hay compost	407 b	191	216 b	51 a
Straw feed	1000 a	172	828 a	77 a
Straw manure	575 c	163	412 b	88 a
Straw compost	573 c	129	444 c	79 a

Note: the same letter after a value in a column means that the value does not significantly differ of those of the same feed in the same column ($P < 0.05$). No statistical analysis is done on NDS since it is calculated from average values of DM-NDF.

daily feed intake stabilised. The digestibility was then determined by weighing all feed offered, and by weighing the left-overs and dung during a period of 6 days. Samples of feed and left-overs were taken and dried at 70°C for 24 hours and ground. They were stored air-dry at room temperature in the laboratory. Special care was taken to store the fresh dung samples in a freezer at –5 to –10°C. After the trial the dung samples were dried and stored in the same way as the samples of feed and left-overs.

Composting was done in buckets to represent the aerobic microbial decomposition. The substrates were chopped at a length of 8–10 cm. They were composted in the same goat stable as where the digestion trial was done, at an ambient temperature of about 15–20°C, in buckets of 12 litre with five ventilation holes of 1.5 cm (diameter) in the lids. Per replicate of 1 kg substrate dry matter (DM), two buckets were filled with 500 g feed DM and water was added to achieve an initial moisture content of 72% required for proper decomposition (Gottschall, 1984). The resulting mix

Table 2. Total *Ninitial*, Total *Nin residue*, NDF-N and ADL-N in hay, straw and their corresponding manures and composts ($mg g^{-1}$ dry matter).

	Total N *initial*	Total N *in residue*	NDF-N	ADL-N
Hay feed	29.2	29.2 a	12.4 a	0.3 a
Hay manure	28.0 *)	5.1 b	1.2 b	0.7 b
Hay compost	29.2	13.2 c	3.9 c	1.8 c
Straw feed	5.6	5.6 a	2.2 a	0.9 a
Straw manure	8.0 *)	3.4 b	1.4 b	1.2 b
Straw compost	5.6	6.5 c	2.7 c	1.6 c

note:– the same letter after a value in a column means that the value does not differ significantly for the same feed ($P < 0.05$).

*) the dwarf goats selected in the feed offered. Therefore, total N in the original material is different in hay manure than in hay feed and higher in straw manure than in straw feed.

was then inoculated with 10 gram ripe fresh compost that was assumed to contain all relevant micro-organisms, even though the composition of its micro/meso-fauna was not determined. Each bucket was turned every third day to aerate and homogenize its content and to achieve a uniform decomposition process in the bucket. The compost was sampled every week and analyzed for ash content as an indicator for organic matter losses. Composting continued until the ash content indicated an organic matter loss in composting equal to that in the digestion process. All treatments were done in four replicates, i.e. four goats as well as four sets of two buckets were used for each treatment.

Laboratory determinations

Two samples of feeds and corresponding manures and composts were analyzed in duplicate for cell wall components according to Goering & Van Soest (1970). The first step in this procedure involves the separation of biomass DM into the neutral detergent solubles (NDS) and the neutral detergent fibre (NDF). The NDS consist of the soluble cell contents: lipids, sugars, starches and protein. The NDF represents the fibrous fractions of the cell wall which can be further fractionated into hemicellulose, cellulose, lignin and ash. Some of these cell wall components, particularly the ADL, contain nitrogen compounds. The acid detergent lignin (ADL) is that part of the NDF that consists mainly of lignin. As such, its composition is very similar to that of 'humus'. In fact, ADL is also determined in a procedure that is similar to the determination of lignin-humus (Stevenson, 1965). Also determined were: dry matter, ash, total nitrogen respectively as per Anonymous (1969), Anonymous (1974) and Anonymous (1966). The nitrogen in the NDF (NDF-N) and in the ADL (ADL-N) was determined on the residue left after the NDF and ADL analyses as indicated above.

Statistical analysis

Data on cell wall components and nitrogen contents were subjected to a two way analysis of variance to test for the main effects: decomposition process and substrates, composting and digestion versus hay and straw, and their interactions.

Results

Decomposition process

The DM digestibility of the hay was 61.5% and that of the straw was 42.5% $((DM_{feed}-DM_{faeces})/DM_{feed}$ in Table 1). After composting, the hay was transformed into a dark coloured mass in which the structure of the hay was largely lost, whereas the structure and colour of the straw could still be recognised after composting. The composting of hay and straw took 81 and 63 days, respectively, to reach similar organic matter losses as the digestion.

Composition of the residues

The pattern of change in absolute amounts of cell wall fractions in the residues was similar during composting and digestion in both the straw and hay substrates (Table 1). Composting of straw resulted in a slight, but significantly higher absolute amount of residual NDF than digestion. In hay, the amounts of residual NDF were not significantly different between digestion and composting. For ADL, the patterns were different. Neither digestion nor composting significantly affected the absolute ADL content in both substrates, though the variation was large in relative terms, within substrates.

In terms of nitrogen fractions, a larger effect of the decomposition process could be observed than in terms of fibre fractions. In both substrates, composting resulted in more N in all fibre fractions than digestion (Table 2). Digestion left only a part of the original N in the faeces and most of the original nitrogen is likely to have been excreted in the urine or lost by volatilization from the faeces: 82% in case of hay and 58% in case of straw ($(N_{initial} - N_{in\ residue})/N_{initial}$ in Table 2). After composting, more nitrogen was left in the residue than after digestion: 45% and 116% of the original amount of N was found in the residues of hay and straw respectively ($N_{in\ residue}/N_{initial}$ in Table 2).

Discussion

Decomposition processes

In spite of its lower digestibility, the composting of straw took less time than that of hay. This may be explained by the difference in absolute amounts to be decomposed, and/or by the more open structure combined with probably better aerobic conditions in the straw compost. The finer texture of the hay made it more difficult to maintain a homogeneous aerobic environment, and also, some parts of the hay may have become too wet and acid for a quick decomposition. Obviously, the feeding of plant biomass to ruminating animals accelerates the overall decomposition process.

Composition of residues

Absolute amounts of ADL in both substrates were not significantly affected by either digestion or composting. This suggests that ADL was neither formed nor lost during the process, or alternatively, that the formation compensated the losses. It also implies that the 'humus' building capacity of a substrate, i.e. residual ADL, is determined by the initial ADL content, rather than by the decomposition process.

The increase of the ADL-N, particularly after composting, indicates either absorption of N by lignin, or formation of 'humus' with a higher N content. If lignin was decomposed at all, the loss of lignin was compensated by the formation of 'humus' like substances. Net formation of lignin is however unlikely, since Võlker *et al.* (1989) found that the absolute amount of lignin and 'humus' like products decreased slowly during storage of manure up to 180 days. Such a decrease indicates that lignin formation does not exceed the decomposition, at least not when the manure is stored in a heap.

The interpretation of these issues is complicated by methodology of the lignin determination. In this trial, as in most other work on this subject, even lignin monomers are generally measured as lignin, here called ADL (Van Soest, 1982). Nevertheless, the initial ADL content of a substrate appears to be an indicator for 'humus' building capacity of a plant biomass. The amount of 'humus' that can be formed appears to be determined indeed by the amount of lignin related substances in the original plant material.

Feeding of biomass to animals rather than to soil micro-organisms does not seem to have a negative effect on the total residue in terms of 'humus' measured as ADL, if all other conditions remain equal. Though speculative, this tendency is supported by the results of Titulaer & Boone (1984). They found that during 8 years of no-tillage under a monocotyledon based crop rotation, the organic matter content of the soil did increase to an extent comparable with that of a newly sown, grazed pasture. Their two treatments can be compared indeed, because soil tillage was not done in either one, and therefore, mineralisation of organic matter can be assumed to be similar (Haynes *et al.*, 1986). Also, similar amounts of 'humus' are added to the soil. For example, if 4500 kg straw contains 77 g ADL kg^{-1}, and 8000 kg grass contains 43 g ADL kg^{-1}, then the total ADL production is 347 and 344 kg ha^{-1} respectively. ADL contents in this rough calculations are based on results of this study and Van Soest (1982).

During composting, much nitrogen was lost from the hay substrate, possibly due to denitrification in anaerobic regions of the compost and the low initial C/N ratio of the hay. In the straw compost, however, the nitrogen content increased marginally but significantly . Nitrogen in the latter case may have been absorbed in the form of ammonia from the air in the goat stable where the buckets were kept. It may also have been fixed by microbes, a possibility suggested by results such as from King *et al.* (1980). Composting resulted in more N in all fibre fractions than digestion did.

It can be concluded therefore that ADL remains more or less constant for all treatments. Since ADL is a resistant fraction of the organic matter, it is a possible indicator for 'humus' building capacity of plant biomass. Moreover, the total amount of 'humus may be the same after composting and digestion. However, the nitrogen fractions behave differently between the two decomposition processes, resulting in different N-release patterns. Also, during digestion a substantial amount of nitrogen is lost through the urine if not properly collected and stored. Further research can be done with different substrates and more complete decomposition processes, for example by continuing the composting of both dung and the intermediate compost as obtained during this trial. This should provide more information about the possibility to predict 'humus' forming capacity of a substrate. Combined with plant growth trials, e.g. in pot trials, further research should also give more insight in the N-release patterns of substrates subjected to the different decomposition processes.

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